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Platinum and Palladium in Mafic-Ultramafic Igneous Rocks, Northwestern Alaska

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Abstract

Extensive bodies of mafic-ultramafic igneous rocks occur in northwestern Alaska. Principal occurrences include Rabbit Creek, Avan River, Misheguk Mountain, Asik Mountain, and Siniktanneyak Mountain areas. Samples from selected sulphide-bearing zones contain some relatively high concentrations of platinum (Pt; 412-1826 parts per billion - ppb) and palladium (Pd; 343-1426 ppb).

Within limits of resolution of optical microscopy, discrete phases consisting of Pt-Pd in major proportions were not recognized. These Pt-Pd concentrations are comparable to many reported concentrations associated with deposits of Pt-Pd-bearing mineralization elsewhere. Given the relatively low modal amounts of sulphides in the Alaska samples (2 to 5 percent), the high Pt and Pd values reported essentially represent concentrations in silicate rocks containing minor sulphides and oxides. There is a direct relationship between concentrations of copper and Pt-Pd, in individual samples, suggesting genetic affiliation.

1. Introduction

A number of extensive bodies of mafic-ultramafic igneous rocks ("complexes") are exposed in northwestern Alaska, north of Kotzebue, in the Noatak River region and environs.

Figure 1 shows the area of interest, while *Figure 2* shows some of the relevant geologic relationships. Principal occurrences include those at Rabbit Creek (float), Avan River, Misheguk Mountain, Asik Mountain, and Siniktanneyak Mountain. Reconnaissance investigations of each of these localities, as well as peripheral surficial materials, have resulted in recognition of relatively high concentrations of platinum (Pt) and palladium (Pd), associated with zones of sulphide minerals.

In keeping with the reconnaissance nature of this work, analyses were made of bulk samples from selected sulphide-bearing zones, but no further attempt was made to concentrate or separate sulphide materials; hence the analytical values include appreciable amounts of silicate minerals as well.

Analyses of Pt and Pd were by fire-assay combined with optical emission spectrography or neutron activation. Other elements were determined by X-ray emission or atomic absorption spectrometry.

Mineral identifications were limited to optical microscopy, supplemented as feasible by X-ray diffraction. A total of thirty-three samples containing appreciable concentrations of Pt and/or Pd are reported on in the present study.

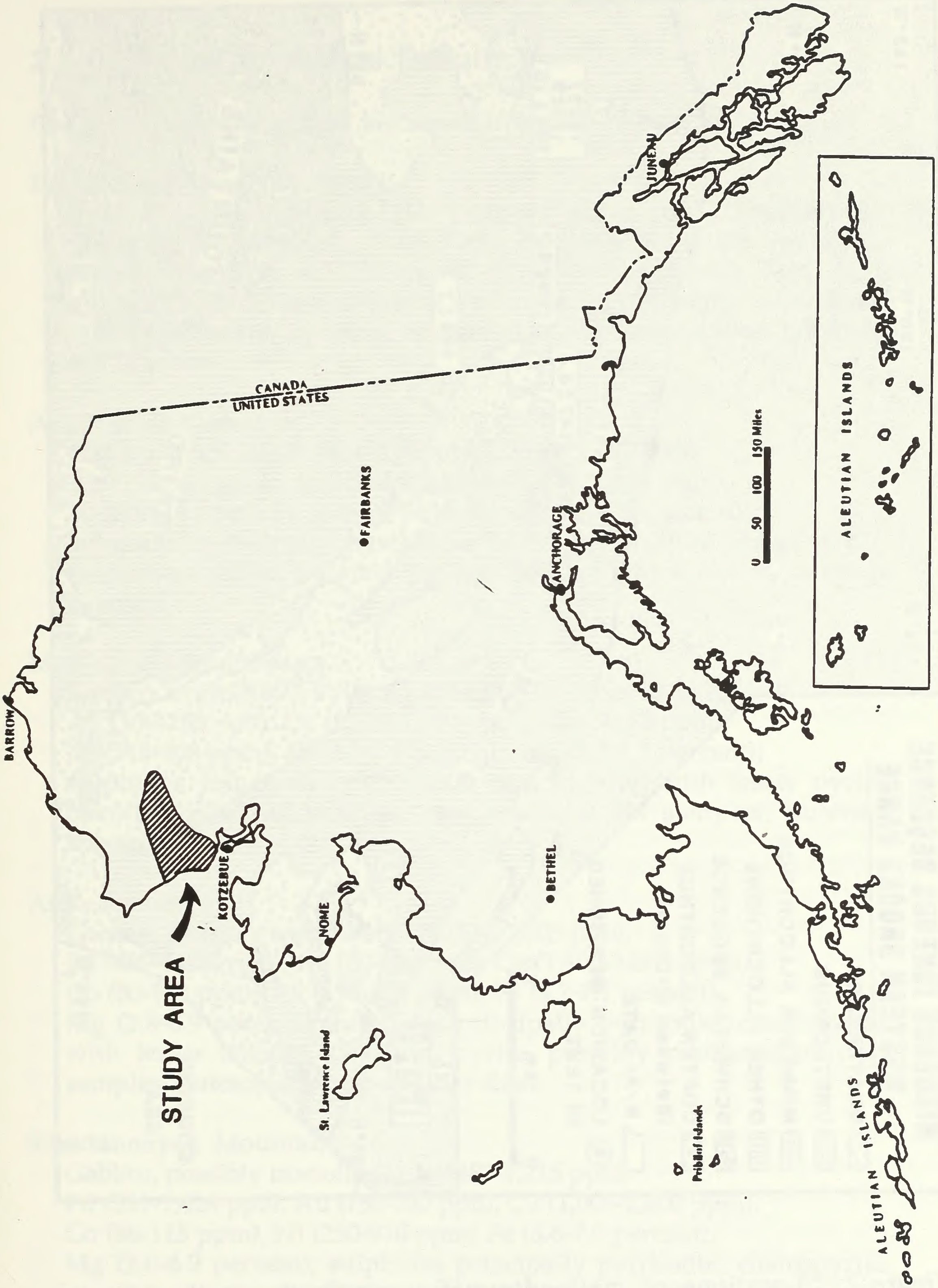

Figure 1. Location of the study area, northwest Alaska.

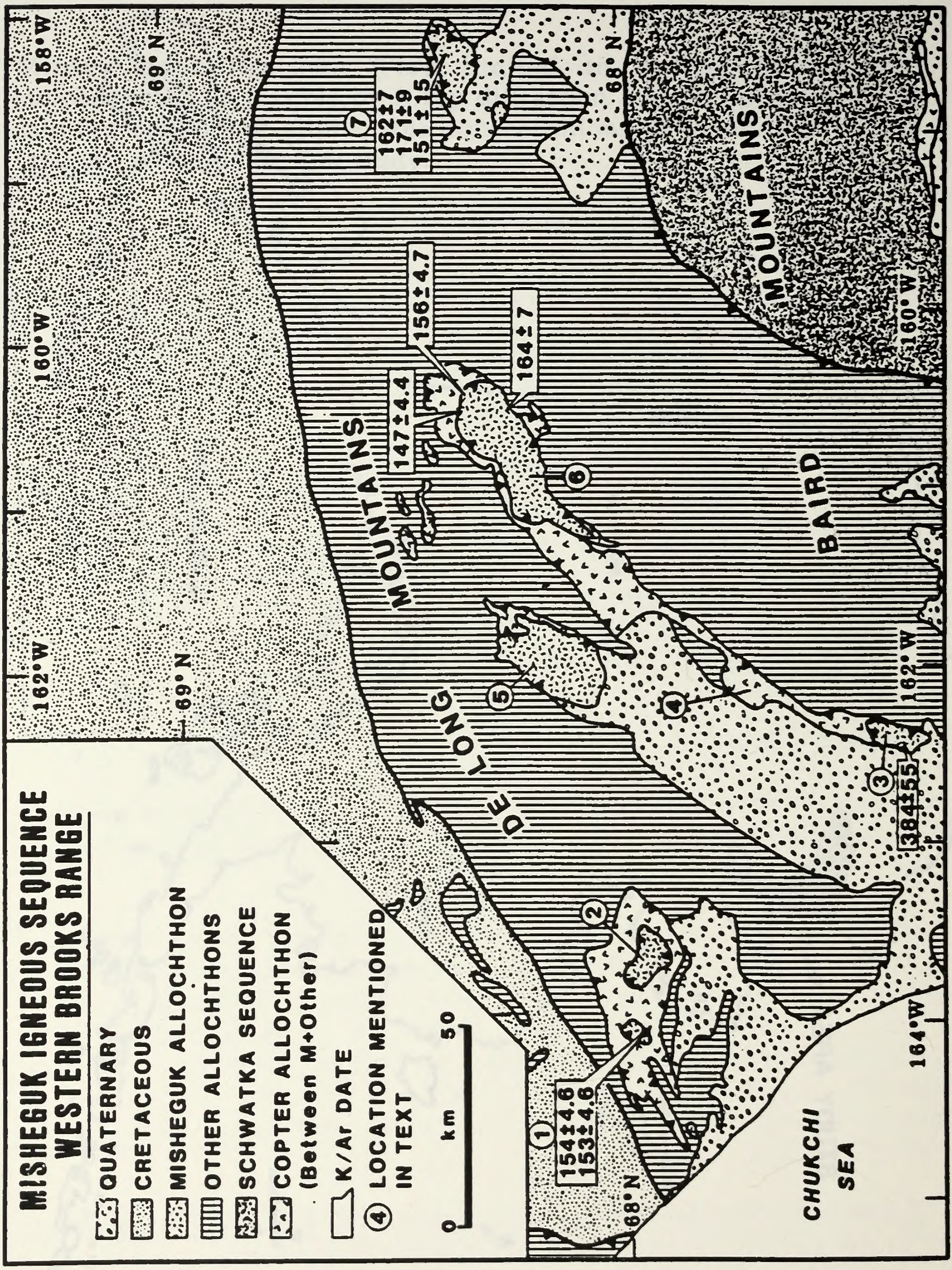

Figure 2. Locations of mafic-ultramafic complexes, northwestern Alaska (from Boak, et al., 1987, p. 738). Localities are as follows: Rabbit Creek Area - south of (2); Avan River area - (5); Misheguk Mountain area - (6); Asik Mountain area - (3); Siniktanneyak Mountain area - (7).

2. Chemical Analytical Results

Chemical analytical results are summarized as follows:

Rabbit Creek (west of Noatak):
Troctolite-gabbro; Pt (412-1,810 parts per billion - ppb), Pd(343-1,090-ppb), Au (209-316 ppb), Cu (1,000-4,200 parts per million-ppm), Co (10-90 ppm), Ni (40-350 ppm), Fe (3.1-6.1 percent), Mg(1.3-6.2 percent); sulphides principally chalcopyrite, pyrrhotite, with lesser bornite, covellite, pyrite; seven samples, rounded cobbles- boulders, not in place.

Avan River Complex:
Gabbro, troctolite; Pt (606-1,502 ppb), Pd (412-990 ppb), Au (110-360 ppb), Cu (1,100-3,500 ppm), Co (19-61 ppm), Ni (60-410 ppm), Fe (3.8-6.9 percent), Mg (1.8-7.6 percent); sulphides principally pyrrhotite, chalcopyrite, with lesser pyrite, bornite, covellite, possibly pentlandite(?); eight samples, outcrop-subcrop.

Misheguk Mountain:
Gabbro, troctolite(?); Pt (512-1,826 ppb), Pd (402-985 ppb), Au (100-250 ppb), Cu (1,500-4,000 ppm), Co (30-82 ppm), Ni (115-808 ppm), Fe (3.9-7.9 percent), Mg (2.1-7.2 percent); sulphides principally pyrrhotite, chalcopyrite, with lesser pyrite, bornite, covellite, possibly pentlandite(?) six samples, outcrop-subcrop.

Asik Mountain:
Gabbro, possibly troctolite(?); Pt (510-1,605 ppb), Pd (480-1,112 ppb), Au (80-220 ppb), Cu (1,100-3,600 ppm), Co (80-125 ppm), Ni (110-655 ppm), Fe (4.2-7.1 percent), Mg (2.8-6.9 percent); sulphides principally pyrrhotite, chalcopyrite, with lesser bornite, covellite, pyrite, possibly pentlandite(?); six samples, outcrop-subcrop-angular float.

Siniktanneyak Mountain:
Gabbro, possibly troctolite(?); Pt (483-1,215 ppb), Pd (511-1,426 ppb), Au (150-240 ppb), Cu (1,000-2,600 ppm), Co (56-115 ppm), Ni (230-910 ppm) Fe (3.6-7.9 percent), Mg (2.0-6.9 percent); sulphides principally pyrrhotite, chalcopyrite, possibly pentlandite(?), with lesser bornite, pyrite, covellite; six samples, outcrop-subcrop.

3. Petrology - Petrography

The rocks are layered-banded, on a scale of 2-3 mm, through tens of meters of section, on reconnaissance field study. The complexes additionally show large scale zonations, featuring apparent ultramafic (lower) and mafic (higher) sequences of igneous "stratigraphy."

Most of the host rocks are crudely to well-layered, on a hand specimen (mm) to outcrop (m) scale, due to contrasting concentrations of the principal constituent minerals. Major phases are plagioclase, olivine, clinopyroxene, orthopyroxene(?), with minor sulphides.

In the sulphide-bearing zones, layers of plagioclase feldspar (An60-70+) alternate with layers in which mafic minerals and associated alteration products are concentrated. The textures are interpreted as igneous cumulates, with cumulus plagioclase, and irregular patches of intercumulus and cumulus mafic material. The latter are generally altered to a complex suite of phases difficult to decipher optically. Primary olivine seems to have been common- ubiquitous, although its presence has since been reduced to mere relict/ghost status in some samples. Cumulus pyroxene was recognized in some samples. The rocks appear to have been subjected to, and modified by, moderate deformational stresses.

Based on bulk mineralogic composition and petrographic characteristics, these rocks are gabbros-troctolites, with individual anorthositic (plagioclase-rich) and dunitic-peridotitic (mafic-rich) zones as petrographic "end-members." Due to strong alteration, the nature of much of the primary mafic phase(s) is now essentially indeterminate. Some of these primary mafic minerals may well originally have been pyroxene, thus necessitating reconsideration of petrologic designations (i.e., some of the "troctolite" might well have been a "gabbro" originally, etc.).

The more mafic zones appear to represent primary igneous olivine and/or clinopyroxene, with associated reaction/alteration products such as pyroxene, amphibole, serpentine, and chlorite, together with black opaque materials (including magnetite) and possibly other optically indeterminate materials.

There are frequently distinct, but complex reaction/alteration zones ("coronas"") between mafic minerals and plagioclase. Such "coronas" are not uncommon in troctolitic rocks elsewhere, and they frequently are involved in strongly altered zones within such rocks. Such alteration has been ascribed variously to deuteric and/or hydrothermal processes.

The plagioclase in the northwest Alaska samples frequently shows alteration to clinozoisite +/- zoisite- epidote along the corona-bordering areas as well. Small patches of sulphide minerals occur interstitial to the rock-forming minerals. The sulphides are principally chalcopyrite and pyrrhotite, with subordinate pyrite, bornite, covellite, and possibly pentlandite recognized. There appears to be some concentration of sulphide phases associated with the more mafic zones, although the sulphides are disseminated fairly uniformly throughout the specimens studied, and are frequently intergranular to plagioclase in areas not obviously associated with mafic alteration.

The general impression is one of primary igneous segregation of plagioclase- and mafic-rich layers, with some reaction relationships at the borders between the phases involved, with deuteric and/or later-stage hydrothermal alteration superimposed upon this.

Magnetite appears to have developed as a consequence of the alteration of previously existing mafics, while the sulphide minerals are somewhat ambiguous as to their paragenesis. Magnetite is cut by chalcopyrite in some areas, indicating later introduction and/or mobilization of sulphides, at least in part, subsequent to alteration of mafic minerals. Much of the chalcopyrite is intimately associated with bornite, pyrrhotite and pyrite (+/-pentlandite?), in apparent mutual exsolution relationships.

Areas in which chalcopyrite-bornite-pyrrhotite, or chalcopyrite-bornite-pyrrhotite (+/- pentlandite?) are in mutual grain-boundary contact with one another are discernible. This suggests exsolution from a higher temperature sulphide phase, attendant upon cooling. This could be interpreted as indicating that the sulphide phase(s) are also of primary igneous origin, and were not introduced subsequently. At least these sulphides would have had to have been introduced at somewhat elevated temperatures if this interpretation is correct. Textural relationships among the silicate, sulphide, and oxide phases present, although not unambiguous, also tend to support this. Occasional occurrences of covellite associated with bornite suggest subsequent alteration/modification of the latter, at yet lower temperatures.

Petrographic descriptions of several gabbroic-troctolitic rocks are given in *Appendix I* as examples of typical relationships observed in samples containing significant concentrations of Pt and Pd.

4. Relationship of PGE to Mineralogy

Several possibilities exist regarding the manner in which the reported Pt and Pd (PGE) concentrations might occur within the northwest Alaska samples. Within the limits of resolution of the optical microscope, no entities which could be identified unequivocally as discrete phases consisting of PGE in major proportions have been recognized. The PGE might be anticipated to occur intimately associated with the sulphide phases present, and chemical and mineralogic data appear to support such a mode of occurrence. Association of PGE, in various forms, with copper and/or nickel sulphide ores is common geochemically, in numerous other reported occurrences elsewhere.

The textural and distributional relationships suggest that much of the sulphide material may have been present at the magmatic stage, perhaps evolving to and through an immiscible sulphide melt phase(s) during the course of petrogenetic events. However, there are also indications of some sort of late-stage concentration and/or introduction of deuteric/hydrothermal fluids, with resultant alteration of pre-existing igneous mafic minerals, particularly in zones where these mafic minerals occur adjacent to primary igneous plagioclase. In the latter zones, reaction relationships between primary igneous phases seem to have provided regions in which subsequent alteration, and perhaps attendant mineralization with sulphides +/- PGE, was enabled to proceed more readily.

Remobilization may be the cause of the observed paragenetic sequences which indicate that at least some of the chalcopyrite transects and, hence, was emplaced subsequent to previously existing magnetite. Similar relationships would explain observed intimate intergrowths of sulphide material with other mafic alteration products as well.

5. Geochemistry

Comparison of the analyses of northwestern Alaska samples with Pt and Pd (PGE) values in recent literature indicate (Naldrett and Cabri, 1976) that the Alaskan materials merit consideration with regard to potentially significant concentrations of PGE, in terms of mineral resources. Concentrations of Pt and Pd in our samples from these northwestern Alaska occurrences are certainly geochemically "anomalous," and are comparable to or greater than many reported concentrations associated with deposits of PGE-bearing mineralization elsewhere.

As can be noted from the relatively low modal percentage of sulphides recognized microscopically in the northwestern Alaska samples (visually estimated to range from two to five percent), the high platinum and palladium values reported essentially represent concentrations in silicate rocks, with minor associated sulphide and oxide phases. This is corroborated by the copper concentrations (1,000-4,200 ppm) reported in the present work. There is a generalized direct relationship recognized between the concentrations of copper and PGE, in individual samples, which suggests genetic affiliation, although there are exceptions. *Figure* 3 illustrates this generalized relationship.

The platinum (Pt) - palladium (Pd) - gold (Au) relationships in the northwest Alaska samples are also of broader geochemical interest. General categories of mafic/ultramafic complexes have been developed in the literature, as defined by various geochemical relationships (Naldrett and Cabri, 1976).

Comparisons of the Pt/Pt + Pd, and Au/Pt + Pd + Au ratios from northwestern Alaska with data on other occurrences worldwide are summarized in *Table 1*. The comparative data do not suggest unambiguous assignment to any one genetic type. The literature values of both of these ratios for "Alpine complexes" and "Alaska-type Complexes" are sufficiently dissimilar to the ratios from the present work as to indicate that the northwestern Alaska rocks most likely do not belong to either of these categories.

The Au/Pt + Pd + Au ratios from the present work most closely resemble those from the "Nickel-Copper Sulphide Ores" category, and do not overlap the ratios given for "Layered Complexes, Excluding Heavily Mineralized Zones." The relatively wide ranges for the Pt/Pt + Pd ratios given for "Layered Complexes, Excluding Heavily Mineralized Zones," and for "Nickel-Copper Sulphide Ores" permit assignment to either of these categories. The northwestern Alaska ratio values for Pt/Pt + Pd, and for Au/Pt + Pd + Au are closely matched by several localities within each of these latter two categories, as displayed in *Tables 2* and *3*.

When the Pt/Pd + Pd ratios are plotted as functions of the Au/Pt + Pd + Pu ratios for the northwestern Alaska samples and for relevant other occurrences worldwide, there is a general clustering of the data points representing northwestern Alaska, with the exception of one "anomalous" data set, which may represent analytical and/or geological factors. In general, the plotted parameters of the northwest Alaska samples lie in a relatively restricted field which is in close proximity to data points representing samples from Sudbury, Pechenga (Petsamo), and the Merensky Reef.

Figure 4 illustrates this, while *Table 4* is a key to the localities plotted in this figure. The significance of these geochemical relationships remains to be elucidated.

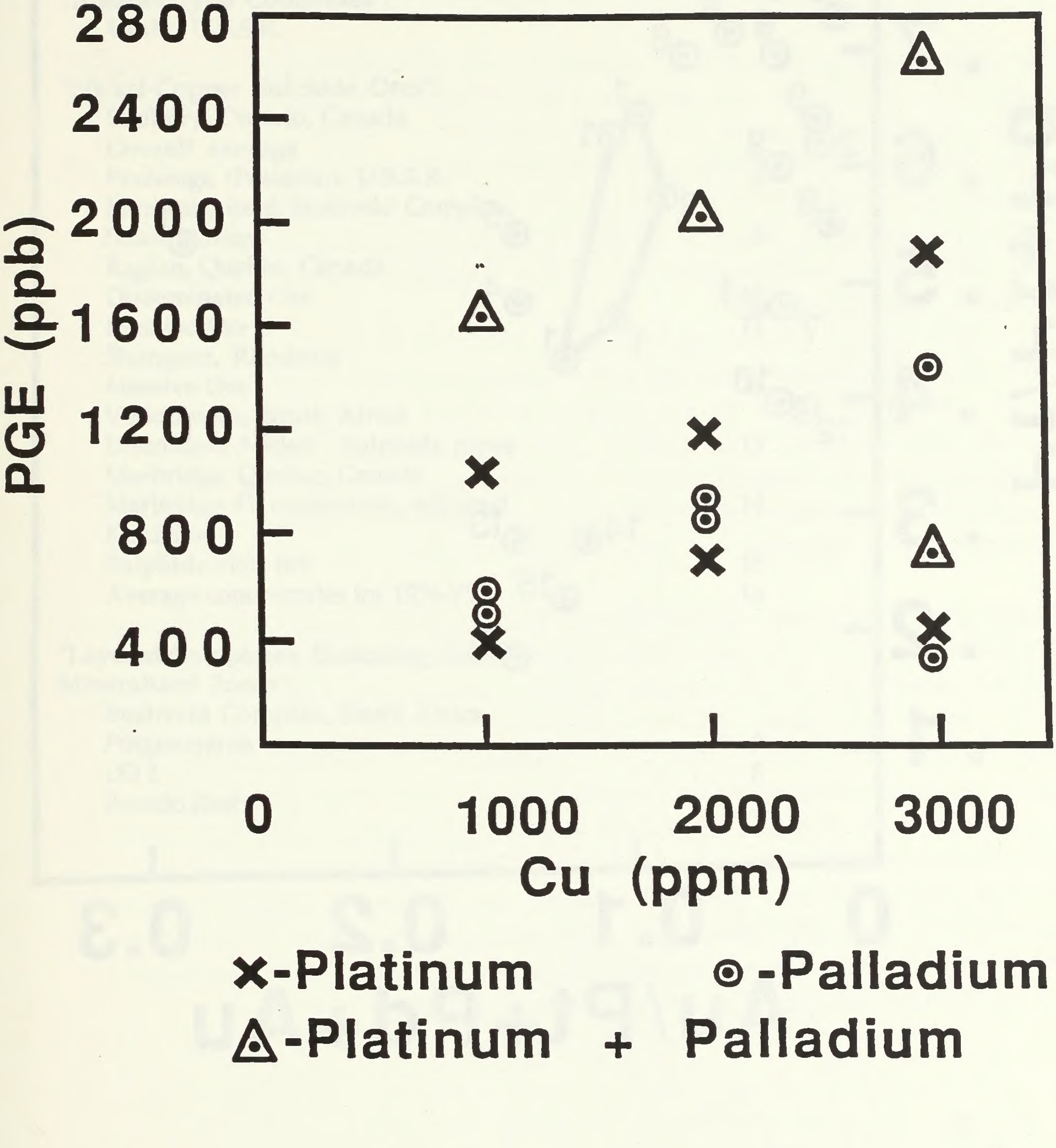

Figure 3. Plot of Platinum-group elements (PGE) as a function of copper (Cu) contents, northwestern Alaska samples.

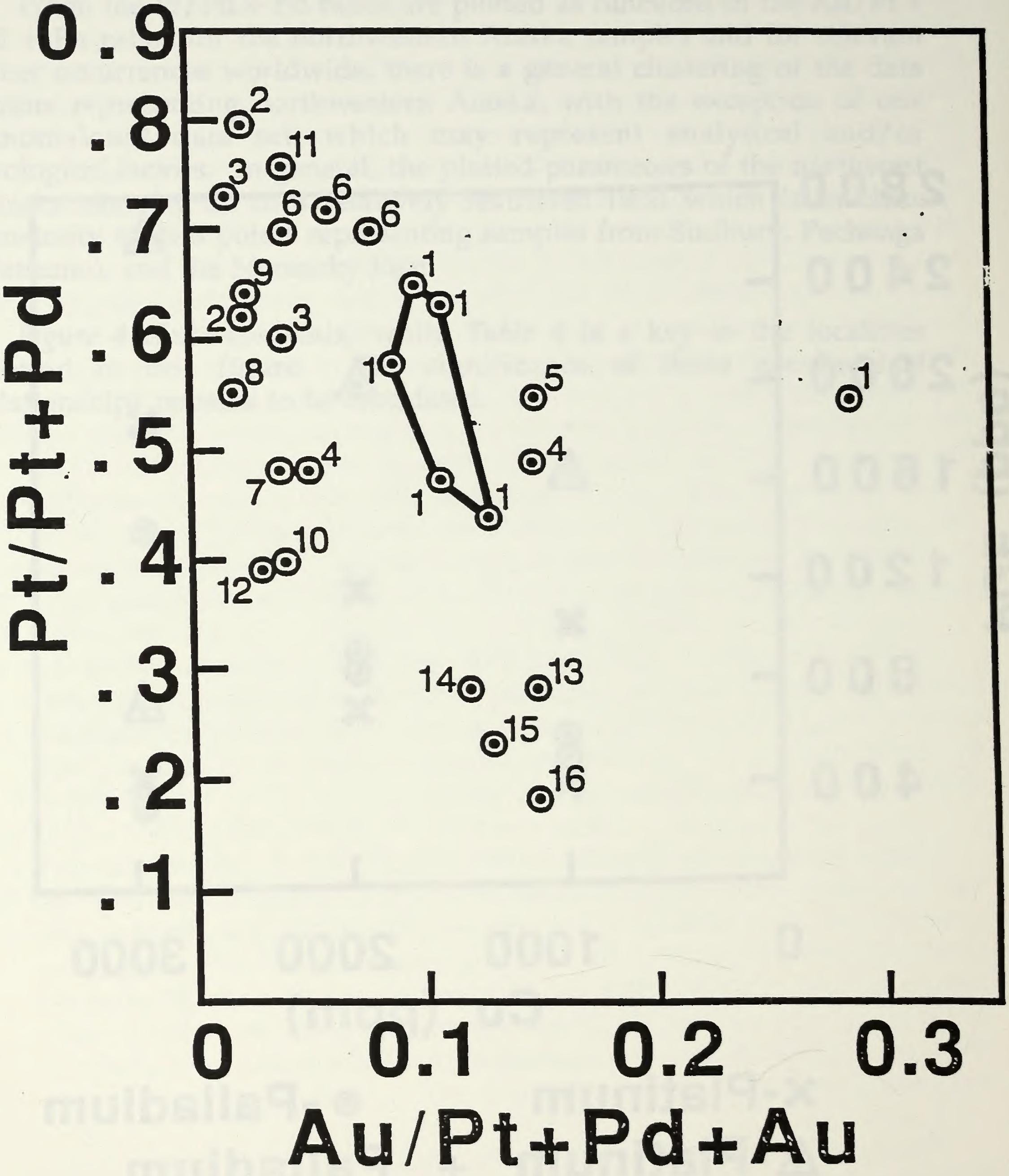

Figure 4. Plot of Pt/Pt + Pd as a function of Au/Pt + Pd + Au, for selected materials from northwestern Alaska and elsewhere. The latter information is from Naldrett and Cabri (1976).

Key to numbers, *Figure 4*.

Category and Locality	Key Number
Northwest Alaska:	1
"Alpine Complexes": Urals, U.S.S.R.	2
"Alaskan-Type Complexes":	
Urals, U.S.S.R.	3
"Nickel-Copper Sulphide Ores":	
Sudbury, Ontario, Canada	
Overall average	4
Pechenga (Petsamo), U.S.S.R.	5
Merensky Reef, Bushveld Complex, South Africa	6
Raglan, Quebec, Canada	
Disseminated Ore	10
Massive Ore	11
Shangani, Rhodesia	
Massive Ore	12
Vlakfontein, South Africa	
Discordant Nickel - Sulphide pipes	13
Marbridge, Quebec, Canada	
Marbridge #1, concentrate, adjusted	14
Kanichee	
Sulphide-rich ore	15
Average concentrates for 1974-75	16
"Layered Complexes, Excluding Heavily Mineralized Zones":	
Bushveld Complex, South Africa	
Potgietersrus	7
UG 2	8
Pseudo Reef	9

6. Geology

These mafic-ultramafic complexes in northwestern Alaska have been interpreted to be of ophiolitic affinity, allocthonous, presently "rootless," and to have been emplaced tectonically into their present structural- geographic contexts, via thrust-faulting of appreciable magnitude (cf.Roeder and Mull, 1978; Boak, et al, 1987). They thus represent key elements in interpretations of local-regional geological relationships, with global implications as well.

Understanding of major aspects of circum-polar geology, particularly as regards the tectonics of the Arctic Basin and adjacent areas, is contingent upon the interpretation of these large igneous bodies. Consideration of the geochemical, mineralogic, and petrologic relationships reported in the present work, in terms of characteristics of ophiolitic sequences elsewhere, should yield insights regarding the nature of these northwestern Alaska igneous rocks, as well as ophiolities in general.

The results reported here provide background for the further more detailed work which will be required to evaluate the significance of the observed geochemical, mineralogic, and petrologic characteristics to considerations of mineral resource potential, as well as to more fundamental aspects of local- regional-global scale geologic relationships and history.

Subsequent to our initial fieldwork (1975) and preliminary appreciation of the PGE potential (1976), the land areas including the northwest Alaska mafic-ultramafic igneous complexes discussed in the present paper have been placed within the boundaries of either the Noatak National Preserve or Cape Krusenstern National Monument. These land categories essentially preclude any further assessment of their potential for mineral resources, other than perhaps limited work of a purely academic research character. Perhaps at some future time, socio-economic factors may be such as to once again permit consideration of these geologic features with regard to possible occurrence(s) of significant concentrations and amounts of platinum-group elements, and perhaps other mineral resources as well.

7. References Cited

Boak, J. M., D. L. Turner, D. J. Henry, T. E. Moore, and W. K. Wallace, 1987, Petrology and K-Ar ages of the Misheguk Igneous Sequence - an allocthorous mafic and ultramafic complex - and its metamorphic aureole, western Brooks Range, Alaska, in Alaskan North Slope Geology, Pacific Section: SEPM and Alaska Geological Society, Bakersfield, p. 737-745.

Cabri, L. J., 1973, New data on phase relationships in the Cu-Fe-S system: Economic Geology, v. 68, pp.443-454.

Naldrett, A. J., and L. J. Cabri, 1976, Ultramafic and related mafic rocks: their classification and genesis with special reference to the concentration of nickel sulfides and platinum group elements: Economic Geology, v. 71, p. 1131-1158.

Roeder, D., and Mull, C. G., 1978, Tectonics of Brooks Range ophiolites: American Association of Petroleum Geologists Bulletin, v. 62, p.- 1696-1713.

Streckeisen, A. L. 1973, Plutonic rocks - classification and nomenclature recommended by the IUGN Subcommission on the Systematics of Igneous Rocks: Geotimes, p. 26-30.

Vaughn, D. J. and J. R. Craig, 1978, Mineral chemistry of metal sulfides: Cambridge University Press, 493 p.

Appendix 1

Summary of Preliminary Petrographic Analyses of Selected Samples from Rabbit Creek, Alaska

(Petrologic classification follows Streckeisen, 1973)

J77-87 Medium-grained troctolite/troctolitic anorthosite. Plagioclase (cumulus) An60+, twinned, weakly zoned, altered by reaction along grain margins adjacent to primary mafic minerals. Layered-like zones/irregular patches of concentration of olivine interstitial to plagioclase, contrasted with zones essentially free of mafic minerals. Barely recognizable olivine relicts, surrounded by generally concentric zones of phases produced at least in part by the reaction relationship between olivine and adjacent plagioclase.

These concentric zones have been at least partially altered (deuteric and/or hydrothermal?), and are presently constituted of recognizable amphibole, chlorite, magnetite, zoisite, +/- serpentine, with complex interrelationships among these and possible other, unrecognized phases. The overall impression here is a situation of reaction between primary cumulus and intercumulus igneous phases, with subsequent (continuous?) deuteric and/or hydrothermal alteration, particularly affecting the mafic minerals.

To some extent, the nature of this alteration seems to be a function of the presence or absence of adjacent plagioclase in any particular instance; the mafics have altered strongly and preferentially, while plagioclase only seems to have been affected along zones where mafics were altering, and where plagioclase adjoined such zones.

Disseminated patches of sulphide phases occur, including occurrences of chalcopyrite interspersed particularly within the reaction/alteration zones described above. Additionally, somewhat larger (0.5 mm maximum observed) patches of chalcopyrite, complexly intergrown with bornite, and less frequently pyrrhotite, pyrite (+/- pentlandite?). The latter intergrowths appear to represent exsolution of these phases from a previously existing sulphide solid solution phase originally stable at a higher temperature (presumably the "iss" as discussed by Cabri, 1973, Vaughn and Craig, 1978,.

Covellite is developed as an apparent further modification of bornite, in scattered occurrences. The sulphide phase relationships recognized are consistent with either a primary igneous or high temperature hydrothermal introduction origin for these materials, relative to their present host rocks. The sulphide phases seem to be spatially concentrated in the alteration zones, though by no means exclusively so. The sample is layered on the hand-specimen scale, with contrasting zones of inversely varying proportions of plagioclase and mafic minerals. Specimens of this sample were studied in polished thin-section.

J77-109 Medium-grained troctolite. Plagioclase (cumulus) An 60+, with intergranular (intercumulus?) olivine, strongly altered (in part reaction "coronas" adjacent to plagioclase). Minor clinopyroxene, amphibole. Alteration materials include serpentine, chlorite, black opaque phases, epidote. The plagioclase and mafic-rich areas are approximately subequal in this specimen. The rock has been moderately-severely affected by deformational stresses.

This specimen was examined only in standard thin-section, hence meaningful characterization of opaque phases, including sulphides, is not feasible at this time. Sulphide phases are disseminated throughout the specimens studied, in apparent (primary igneous?) intergranular textural relationships with the plagioclase as well as the altered mafic minerals. On the hand specimen scale, the sample is layered, with contrasting zones with inversely varying proportions of plagioclase and mafic minerals.

J77-112 Medium grained olivine-gabbro/leuco-troctolite. The sample is layered on the hand-specimen scale, with contrasting zones of inversely varying proportions of plagioclase (cumulus) and mafic minerals. In the gabbroic portion of the sample, plagioclase is An65+, slightly bent and strained. Mafic (cumulus and intercumulus) minerals are clinopyroxene, orthopyroxene, and olivine, with patches and poikilitic areas of pleochroic amphibole. If the amphibole is considered as a primary igneous crystallization phase (?), there is little apparent alteration of the mafic minerals in this specimen.

Some chlorite is recognizable, and opaque phases, with slight development of serpentine were also discernible throughout the zones of mafic mineral concentration. The specimens were examined only in standard thin-section, hence definitive characterization of opaque phases was not feasible. The sample appears to have been subjected to only relatively slight deformational stress, although this is somewhat questionable in that stress relief in the rocks may have taken place preferentially within the finer-grained mafic-rich zones.

In the leuco-troctolitic portion of the sample, the plagioclase (cumulus) is An65+. The primary (intercumulus?) igneous mafic minerals (olivine +/- pyroxene?) are very strongly altered to a complex composite of phases, of which chlorite and serpentine are recognizable. There is a decided reaction corona developed along the plagioclase grains where they lie adjacent to the mafic material, reminiscent of the relationships described in sample J77-87. Patches of sulphides (0.4 mm maximum size) are disseminated throughout the specimen studied, intergranular to the plagioclase as well as the altered mafic materials. This portion of sample J77-112 seems quite similar to sample J77-87.

J77-128 Medium-grained olivine gabbro. Mafic minerals (cumulus +/- intercumulus) include clinopyroxene, olivine, and perhaps some minor orthopyroxene, slightly - moderately altered to serpentine, chlorite and black opaque phases. Plagioclase (cumulus) is An60+. Fractures which traverse the specimen studied are accompanied by alteration of mafic minerals and plagioclase quite similar to the "corona" relationships described between alteration of mafic minerals in samples J77-87, 109, 112, and 140. This might indicate that late stage deuteric and/or hydrothermal alteration processes were, in fact, responsible for these "corona-like" relationships, but clarification of this situation will require more detailed study.

The alteration in the particular specimen examined is definitely fracture-controlled, and the spectrum of serpentine - chlorite - black opaque phases -

zoisite/clinozoisite - epidote alteration products is well developed. Perhaps significantly, in this gabbroic rock, there are no recognizable sulphide phases associated with either the primary igneous minerals or the alteration materials. The specimen was only studied in standard thin section.

Table 1.
Comparison of platinum (Pt) - palladium (Pd) - gold (Au) relationships, northwest Alaska, with other localities worldwide (from Naldrett and Cabri, 1976).

Locality	Pt/Pd + Pd (range of values)	Au/Pt + Pd + Au (range of values)
Northwest Alaska	0.44 - 0.65	0.09 - 0.29
"Alpine Complexes"	0.62 - 0.91	0.022
"Alaskan-type Complexes"	0.60 - 0.89	0.015 - 0.004
"Layered Complexes, Excluding Heavily Mineralized Zones"	0.29 - 0.69	0.017 - 0.037
"Nickel-Copper Sulphide Ores"	0.11 - 0.76	0.02 - 0.15

Table 2.

Comparison of Pt/Pd + Pd ratios, northwest Alaska, and selected other occurrences worldwide; the latter from Naldrett and Cabri (1976).

Locality	Pt/Pd + Pd (range)
Northwest Alaska	0.44 - 0.65
Layered Complexes, Excluding Heavily Mineralized Zones	
Stillwater Complex, Montana:	
Bronzitite Member	0.64
Upper Bronzitite	0.50
Banded and Upper Zone	0.69
Bushveld Complex, South Africa	
Potgietersrus	0.48
UG 2	0.55
Pseudo Reef	0.64
Main Magnetite	0.45
Nickel-Copper Sulphide Ores	
Sudbury, Ontario, Canada:	
Overall average	0.48 - 0.49
Pechenga (Petsamo), U.S.S.R	0.55
Merensky Reef, Bushveld Complex, South Africa	0.70 - 0.72
Raglan, Quebec, Canada:	
Disseminated ore	0.40
Massive ore	0.76
Shangani, Rhodesia:	
Massive ore	0.39

Table 3.
Comparison of Au/Pt + Pd + Au ratios, northwest Alaska and selected other occurrences, worldwide, the latter from Naldrett and Cabri (1976).

Locality	Au/Pt + Pd + Au (range)
Northwest Alaska	0.09 - 0.29
Nickel-Copper Sulphide Ores	
Merensky Reef, Bushveld Complex, South Africa:	
Western Platinum Mine	0.06 - 0.08
Vlakfontein, South Africa:	
Discordant nickel sulphide pipes	0.15
Sudbury, Ontario, Canada:	
Overall average	0.15
Pechenga (Petsamo), U.S.S.R.	0.15
Marbridge, Quebec, Canada:	
Marbridge #1, concentrate, adjusted	0.12
Kanichee:	
Sulphide-rich ore	0.13
Average concentrates for 1974 - 75	0.18

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